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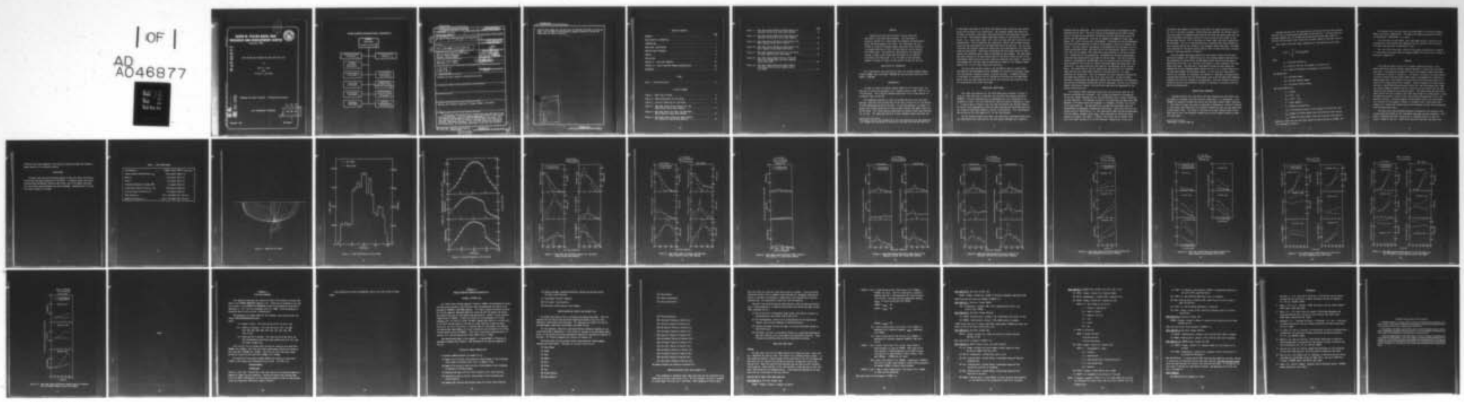

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

SHIP MOTION AND FLEXURE DATA BASE FOR THE CG-26

by

Harry D. Jones

and

William R. McCreight

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SHIP PERFORMANCE DEPARTMENT

November 1977

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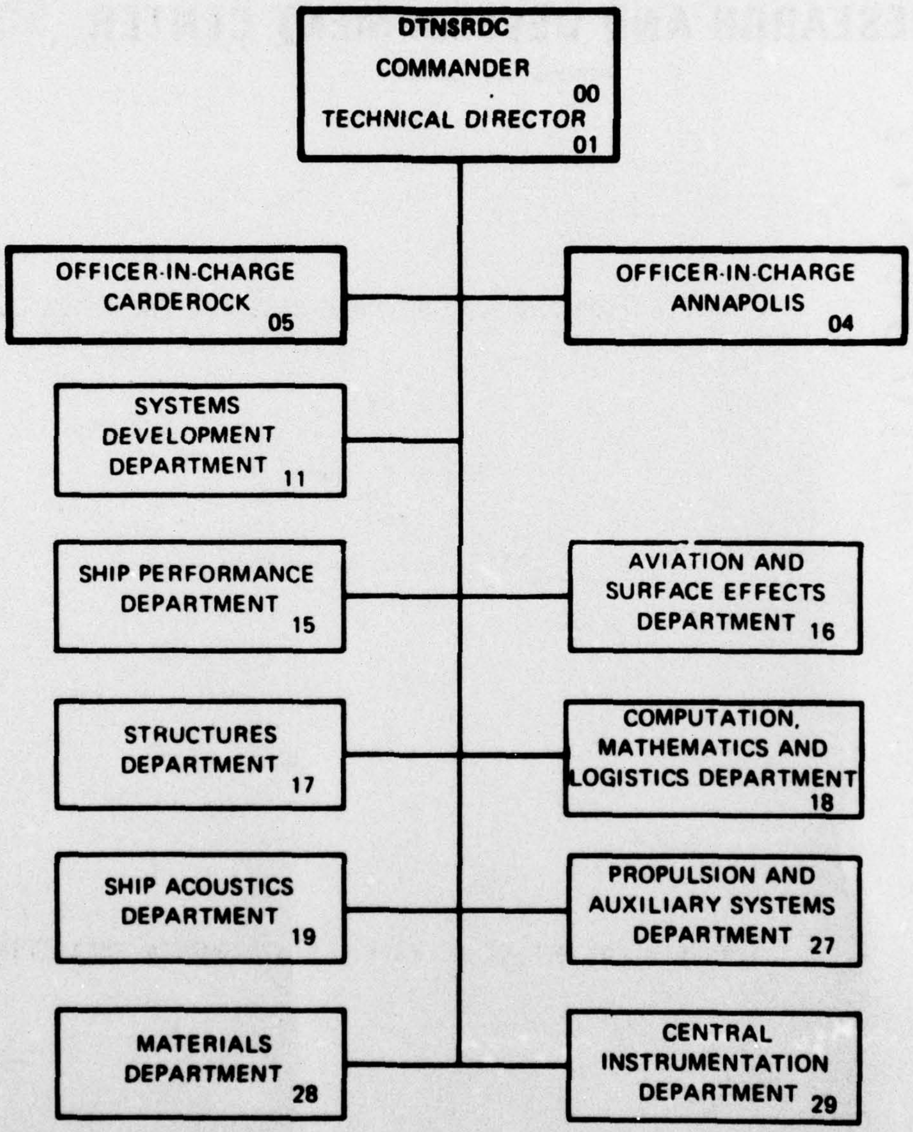

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A generalized ship motion and hull flexure data base applicable to the CG-26 was developed. This data base is stored on the David W. Taylor Naval Ship Research and Development Center CDC 6700 computer disk packs. This data base consists of both an extensive frequency domain data base and an extensive time domain data base of the rigid body motions and the angular hull deflections. The conditions represented in the data base include a

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range of ship speeds and sea conditions at headings from head to following seas. Also included are the necessary computer programs to access and manipulate the data as required.

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ABSTRACT

A generalized ship motion and hull flexure data base applicable to the CG-26 was developed. This data base is stored on the David W. Taylor Naval Ship Research and Development Center CDC 6700 computer disk packs. This data base consists of both an extensive frequency domain data base and an extensive time domain data base of the rigid body motions and the angular hull deflections. The conditions represented in the data base include a range of ship speeds and sea conditions at headings from head to following seas. Also included are the necessary computer programs to access and manipulate the data as required.

ADMINISTRATIVE INFORMATION

This investigation was authorized by Naval Sea Systems Command Program Element 63564N, Task Area Number S0407055 and was performed under Work Unit Number 1-1568-881.

INTRODUCTION

In order to access the overall combat capability of surface ships, the Navy has initiated the development of a topside synthesis model (TSM) for use in ship design. The predicted responses generated in this investigation will be used as input to the TSM.

The responses necessary as input to the TSM consist of the rigid body motions, velocities and accelerations of the ship's origin* as well as motions of other designated points on the ship. It was also necessary to predict the angular hull girder deflections to help further evaluate the combat capability of the CG-26. This investigation established the extensive data base necessary for the TSM. This data base consists of both frequency domain data base and

*The origin lies at the intersection of the calm waterplane and the perpendicular through the ship center of gravity for the ship with zero heel and trim.

a time domain data base of the CG-26 rigid body motions, velocities and accelerations and the angular hull deflections. The frequency domain data base also includes the motions, velocities, and accelerations of two additional locations on the ship. The frequency domain data base consists of the motions of the origin, i.e., surge, sway, heave, roll, pitch, and yaw, and their velocities and accelerations. Also included are the transverse, lateral, and vertical motions, velocities and accelerations of two additional points on the ship. The vertical, transverse and torsional deflection angles were also predicted for five locations along the ship length. These were investigated for both long-crested and short-crested sea conditions over a range of headings and ship speeds. The time domain data base consists of the same predictions for the ship's origin as well as the same angular deflections but at four locations along the ship length. These were investigated over the same range of headings and speeds as the frequency domain analysis for a set of long-crested sea conditions.

This data base has been stored on the CDC 6700 at David W. Taylor Naval Ship Research and Development Center (DTNSRDC) on a series of disk packs, along with the necessary computer programs to access the data. A computer program is available to interpolate the hull deflection time histories for additional points along the ship length and to provide short-crested time histories from the long-crested time history data base.

CONDITIONS INVESTIGATED

This study was conducted for the CG-26 (body plan presented in Figure 1) using its load conditions as obtained from the Naval Ship Engineering Center (NAVSEC). The ship characteristics as designated for this investigation are presented in Table 1 with the longitudinal load distribution presented in Figure 2. It may be seen in Figure 2 that the load distribution was revised; however, the bulk of this computational study had been completed and the differences were not viewed as significant enough to warrant recalculations. This investigation was carried out for ship speeds of 5, 10, 20, and 25 knots.

For the frequency domain data base, the statistical rigid body motions and hull deflections were predicted for the ship speeds indicated for a range of

headings and sea conditions. The rigid body motions were investigated at three locations on the ship. The first location investigated was the ship's origin which is located on the centerline coincident with the longitudinal center of gravity and the waterplane. Here the six degrees of freedom of surge, sway, heave, roll, pitch, and yaw were investigated. Predictions of the displacements, velocities and accelerations of each of these modes of motion were made at the origin. The next location investigated is designated as the Gun Mount with its location being 59.4 meters (195 feet) aft of the longitudinal center of flotation (LCF) and 5.6 meters (18.4 feet) above the waterline on the ship's centerline. Predictions of the longitudinal, transverse and vertical displacements, velocities and accelerations were made for the Gun Mount. The third location studied is designated as the 48C Radar with its location being 14.6 meters (48 feet) forward of the LCF and 31.1 meters (102 feet) above the waterline on the centerline. The same predictions were made for the 48C Radar as for the Gun Mount. The predictions of the hull deflections were made for five locations along the ship with these being relative to the Station 0.5, i.e., zero deflection at Station 0.5. The five locations for which these hull deflections were made were Stations 1.5, 5.5, 10.5, 15.5, and 18.5. At each of these locations response amplitude operators (RAO's) were predicted for the transverse and vertical displacement deflections and the transverse, vertical, and torsional angular deflections; however, the statistical data base was generated for the angular deflections only.

The frequency domain data base consists of the statistical data for the motions and deflections indicated. This includes an extensive investigation of the four speeds indicated (5, 10, 20, and 25 knots) over a range of headings and sea conditions. The headings included in this data base are head waves (180 degrees) to following waves (zero degrees) in 15-degree increments for a total of thirteen headings. The sea conditions included were described using the Bretschneider two-parameter mathematical formulation. Statistical data for the motions and hull deflections, i.e., root mean square (RMS) and period associated with the largest response cycles (T_{0E}), were predicted for significant wave heights of 2 meters (6.5 feet), 3.1 meters (10.2 feet) and 5.2 meters (16.9 feet) with modal periods of 6, 8, and 9 seconds, respectively, as well as a

significant wave height of 3.0 meters (10.0 feet) for modal periods of 7, 9, 11, 13, 15, 17, 19, and 21 seconds. Calculations were made for the 10-foot significant wave height only because predictions of both mild and severe conditions are readily available from these results by direct scaling of wave height at the desired modal period. This is possible as linear theory was used in generating the data base. For all of the sea conditions indicated, both long-crested and short-crested results are included in the frequency domain data base. The headings indicated for the short-crested results refer to those from which the major portion of the wave energy is directed.

The time domain data base consists of time history results for the same motions and angular hull deflections as for the frequency domain data base with the exceptions of the Gun Mount and 48C Radar motion results and the angular deflections at Station 1.5. The wave time history is also included in the time domain data base. The conditions investigated include the same speeds and headings as for the frequency domain results for the 2, 3.1, and 5.2 meter significant wave heights as indicated; however, in this case only long-crested results are included. As indicated, the software is available to produce short-crested time histories from the long-crested results and the additional headings necessary for this are included in the data base. The time histories were predicted for each of the conditions indicated to represent a duration of one-half hour of ship operation.

COMPUTATIONAL PROCEDURE

Transfer functions for ship motion and load response were calculated using the theory of Salvesen, Tuck and Faltinsen, Reference 1*, as implemented in the DTNSRDC six degree-of-freedom Ship Motion and Sea Loads Program (SMSL), Reference 2. The limits on surge, sway and yaw described in Reference 3, ordinarily applied in later steps, were applied to the transfer functions so that the sea loads would reflect these limits. The effect is believed to be small because these limits apply only at very low encounter frequencies, at which dynamic effects on loads are quite small.

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*References listed on page 33.

Transfer functions for the flexures were calculated from the load transfer function using a simple static beam model of the ship hull. Uniform loads and torsional moments per unit length were calculated from the SMSL output of vertical and horizontal shear forces and torsional moment at each half station.

From simple structural theory (Reference 4), the deflections are found from

$$\theta_i(x) = \int_{x_o}^{x} C_i(\xi) V_{i+3}(\xi) d\xi$$

where

θ_1 = torsional deflection

θ_2 = slope of vertical displacement of neutral axis

θ_3 = slope of horizontal displacement of neutral axis

the moments are

V_4 = torsional moment

V_5 = vertical bending moment

V_6 = horizontal bending moment

and the constants are

$C_1 = 1/(GC_T)$

$C_2 = 1/(E \cdot I_{yy})$

$C_3 = -1/(E \cdot I_{zz})$

G = shear modulus

E = modulus of elasticity

C_T = a structural constant = polar moment of inertia for a bar

I_{yy} = moment of inertia about y-axis of structure cross section

I_{zz} = moment of inertia about z-axis of structure cross section

Numerical values for the last three quantities were provided by NAVSEC, and are presented in Figure 3.

The transfer functions were used by program ESPEC to calculate frequency domain statistical computations. The theory and equations executed by ESPEC are documented in References 3, 5, and 6.

Time histories of wave height, ship rigid body motions, velocities, and accelerations, and flexures were computed from the transfer functions using the theory and equations of References 3 and 7.

The time history data base, stored on disk packs as described in Appendix A, can be easily accessed using the program THACES, for which a user's manual is provided in Appendix B.

RESULTS

The CG-26 data base consists of a frequency domain data base, a time domain data base, and the computer program necessary to access the time domain data base. A representative sample of some of the frequency domain data base is presented in Figures 4 through 13. In Figures 4 through 8, the long-crested and short-crested root mean square (RMS) results are compared as a function of heading angle for a ship speed of 25 knots and a significant wave height of 3.1 meters with a modal period of 8.0 seconds. Figure 9 compares the long-crested and short-crested RMS deflection angle results for the long-crested worst heading results (based on Station 18.5) as a function of ship station for the same speed and wave height as the previous figures. The long-crested RMS deflection angle results for the 3.0 meter significant wave height are investigated in terms of modal wave period in Figure 10 for the stations indicated again for a ship speed of 25 knots. The worst heading (long-crested) results are investigated as a function of ship speed in Figures 11 through 13 for a significant wave height of 3.1 meters and a modal period of 8.0 seconds for both long-crested and short-crested predictions.

The costly and time-consuming procedure of generating the extensive time history data which makes up the time domain data base has been completed. This data is available and easily accessible, as indicated herein, to meet the specific needs of the user. Some of the statistics derived from these time

histories have been compared to the statistics derived through the frequency domain analysis with favorable results.

CONCLUSIONS

The most time- and cost-consuming aspects of the ship motion and flexure predictions have been completed for the CG-26. A frequency domain data base, including RAO and RMS/T_{OE} response predictions, and a time domain data base and time history access program have been developed. Documentation for using the access program is included.

TABLE 1 - SHIP PARTICULARS

Displacement, Δ	8458.9 tonnes (8594.6 long tons)
Length between Perpendiculars, L_{PP}	159.7 meters (524.0 ft)
Beam, B	16.6 meters (54.4 ft)
Draft, T	6.2 meters (20.2 ft)
Transverse Metacentric Height, $\overline{GM}$	1.5 meters (4.97 ft)
Longitudinal Center of Gravity, LCG	85.3 meters (279.8 ft)
Vertical Center of Gravity, KG	6.0 meters (19.8 ft)
Shear Modulus, G	8.3×10^4 MN/m^2 (12×10^6 psi)
Modulus of Elasticity, E	20.7×10^4 MN/m^2 (30×10^6 psi)

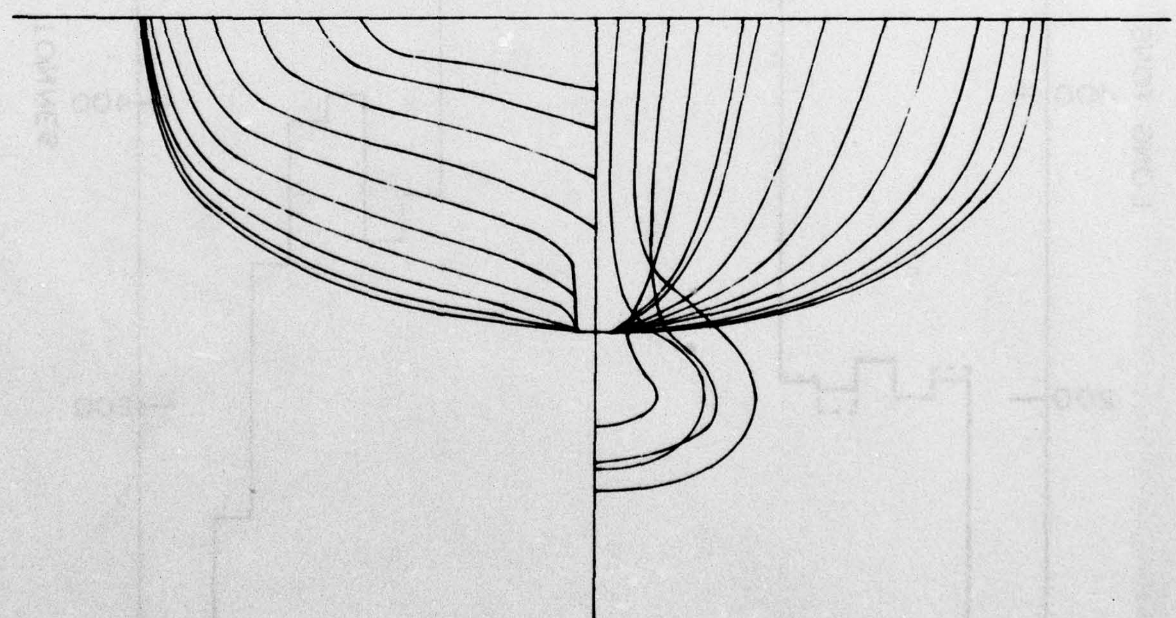

Figure 1 - Body Plan of CG-26

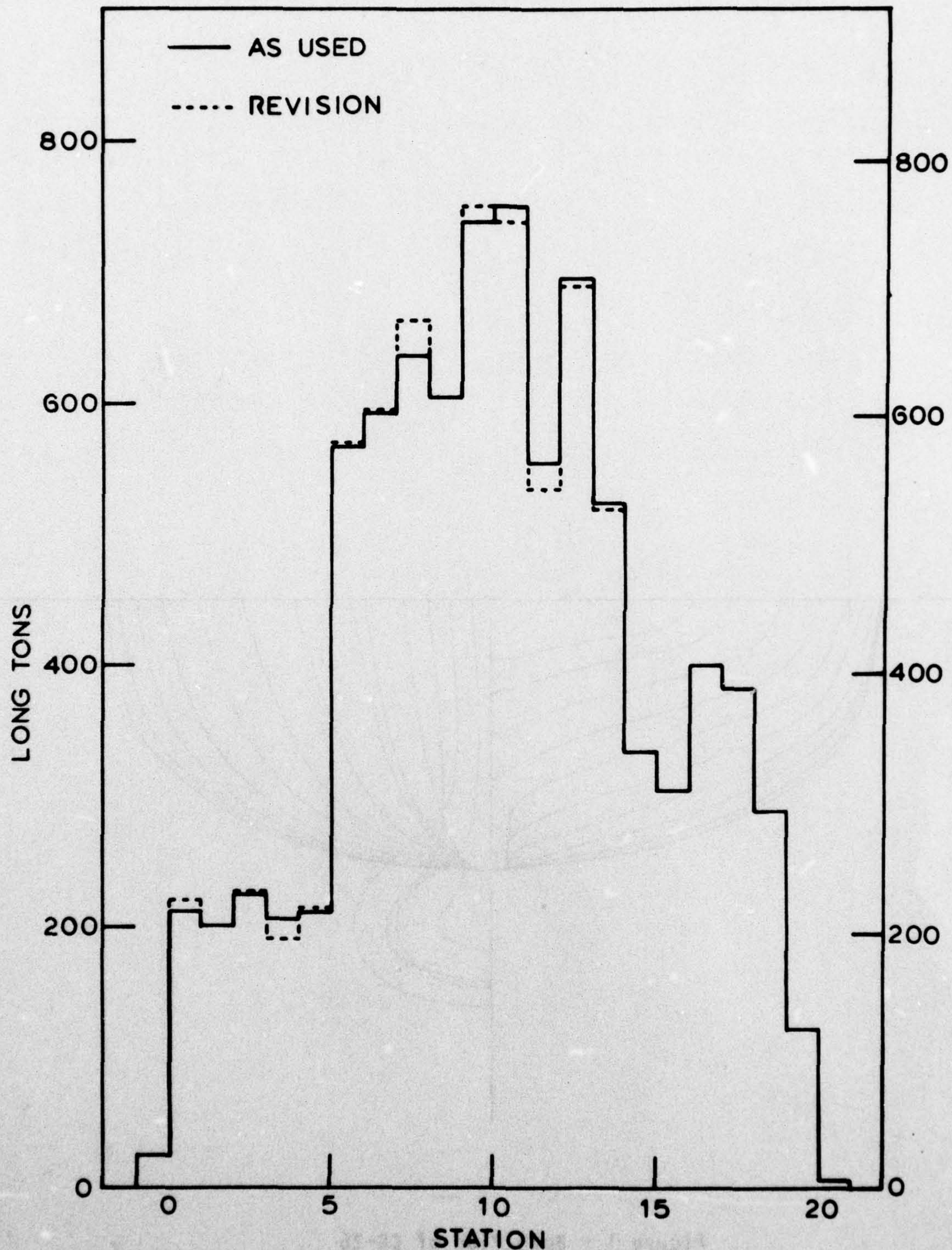

Figure 2 - Load Distribution for the CG-26

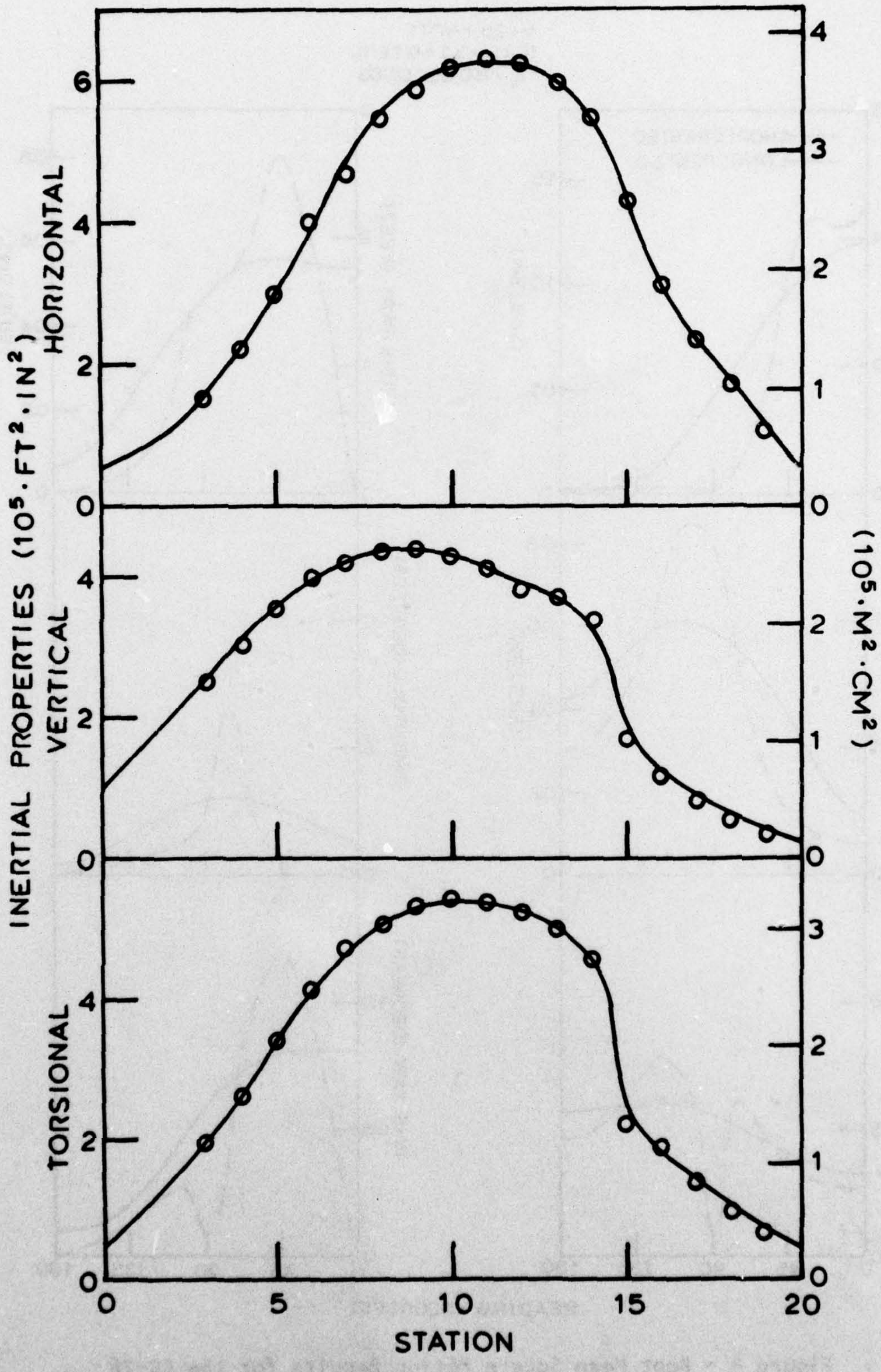

Figure 3 - Inertial Properties for the CG-26

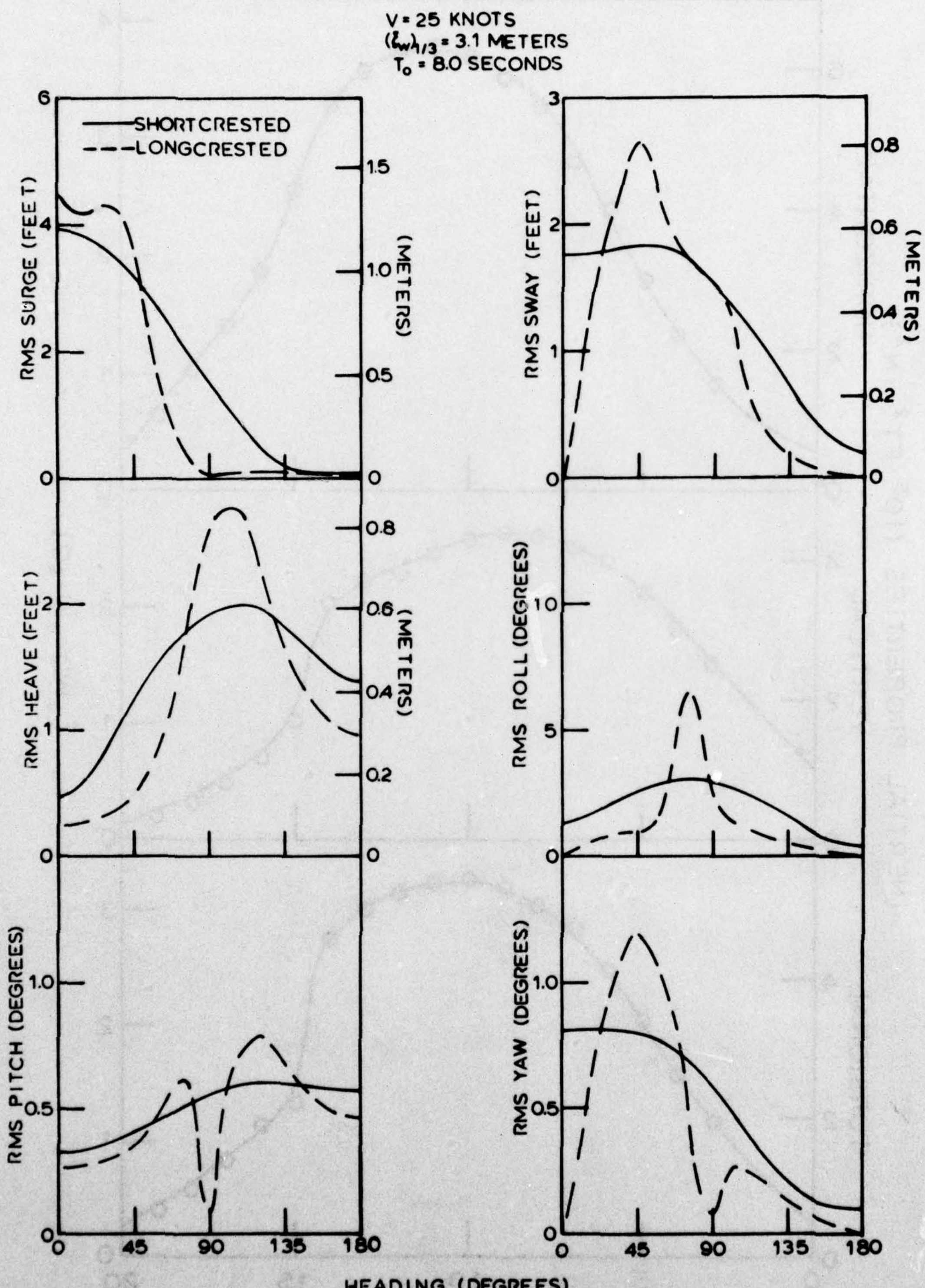

Figure 4 - Root Mean Square Motion Results for the CG-26 Origin versus Wave Heading

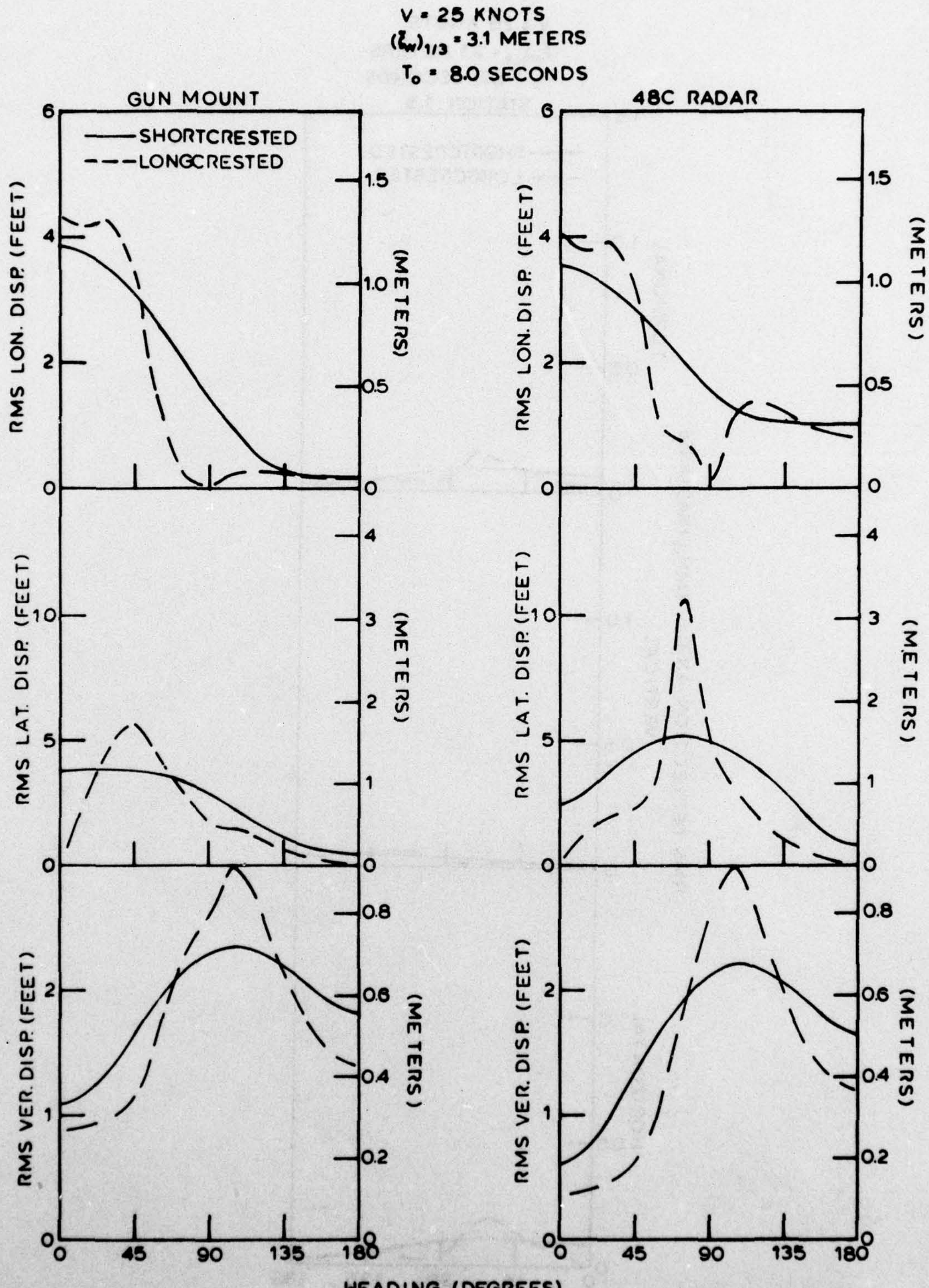

Figure 5 - Root Mean Square Gun Mount and 48C Radar Motion Results versus Wave Heading

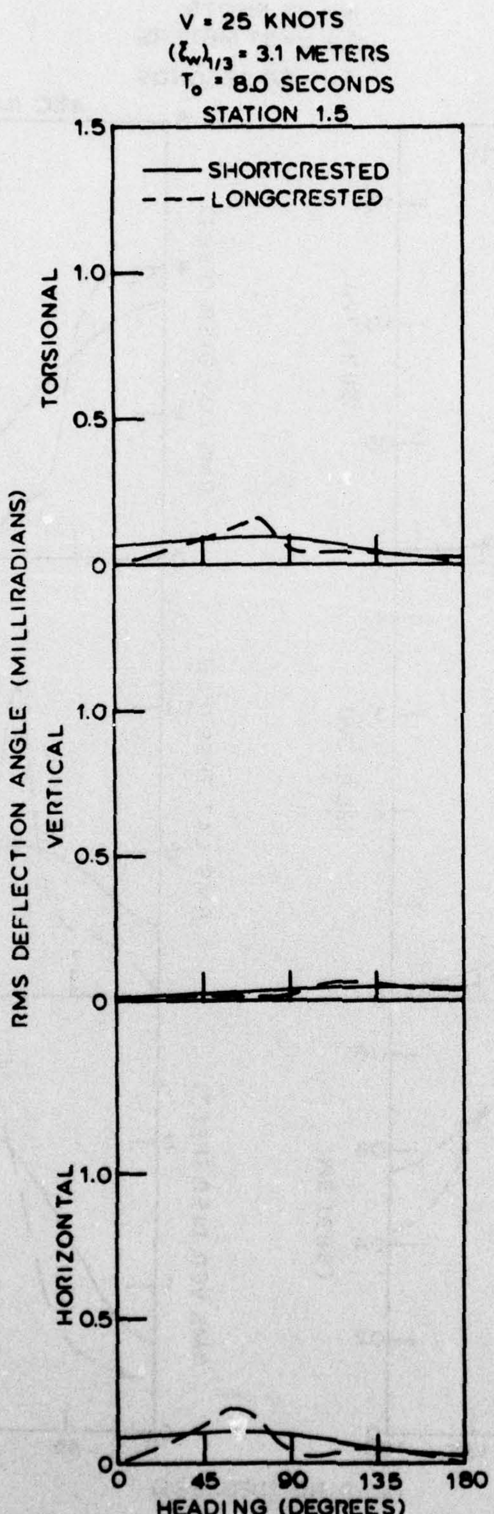

Figure 6 - Root Mean Square Deflection Angle Results for Station 1.5 versus Wave Heading

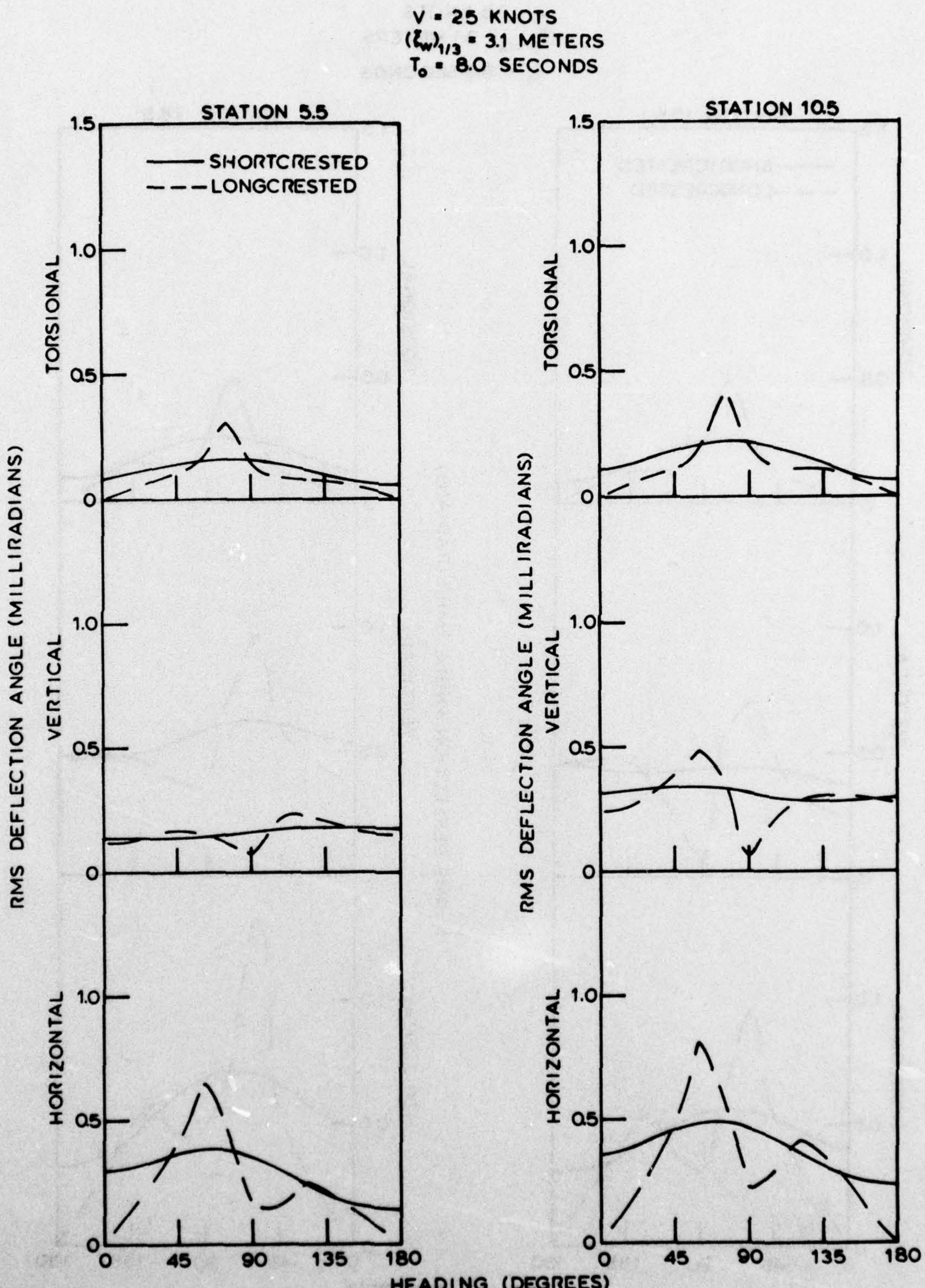

Figure 7 - Root Mean Square Deflection Angle Results for Stations 5.5 and 10.5 versus Wave Heading

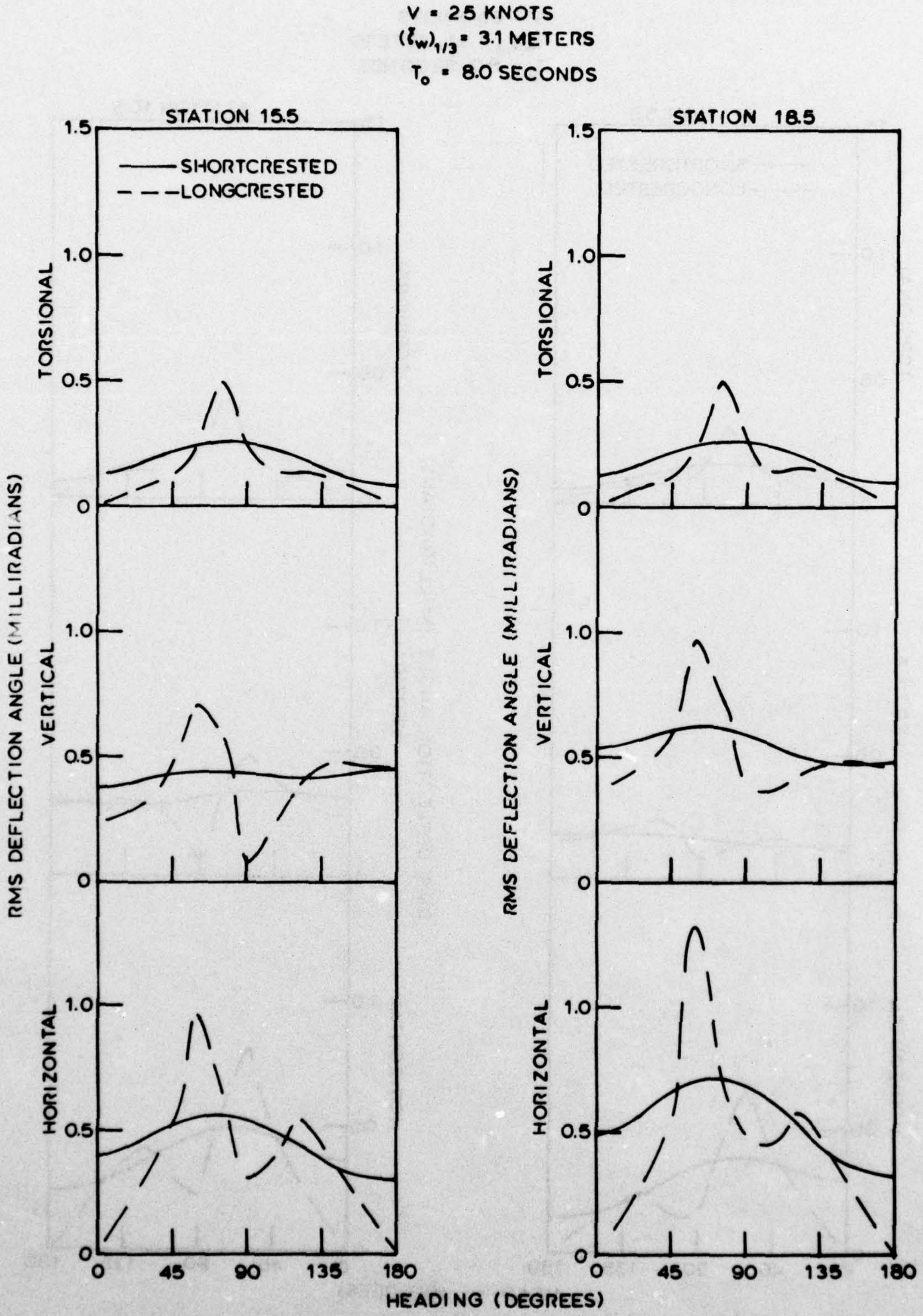

Figure 8 - Root Mean Square Deflection Angle Results for Stations 15.5 and 18.5 versus Wave Heading

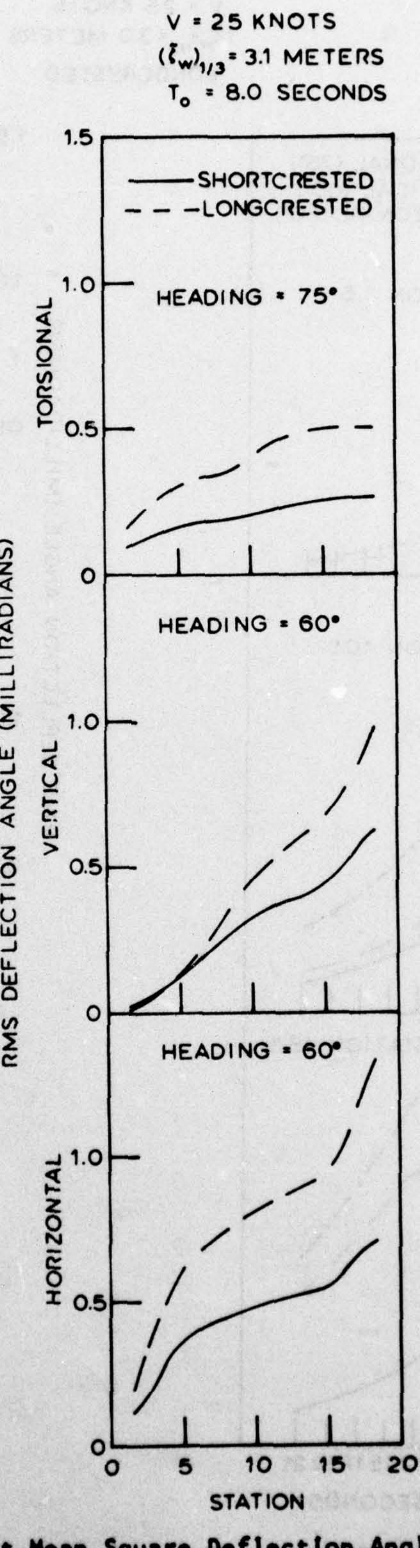

Figure 9 - Root Mean Square Deflection Angle Results for Worst Heading versus Ship's Station

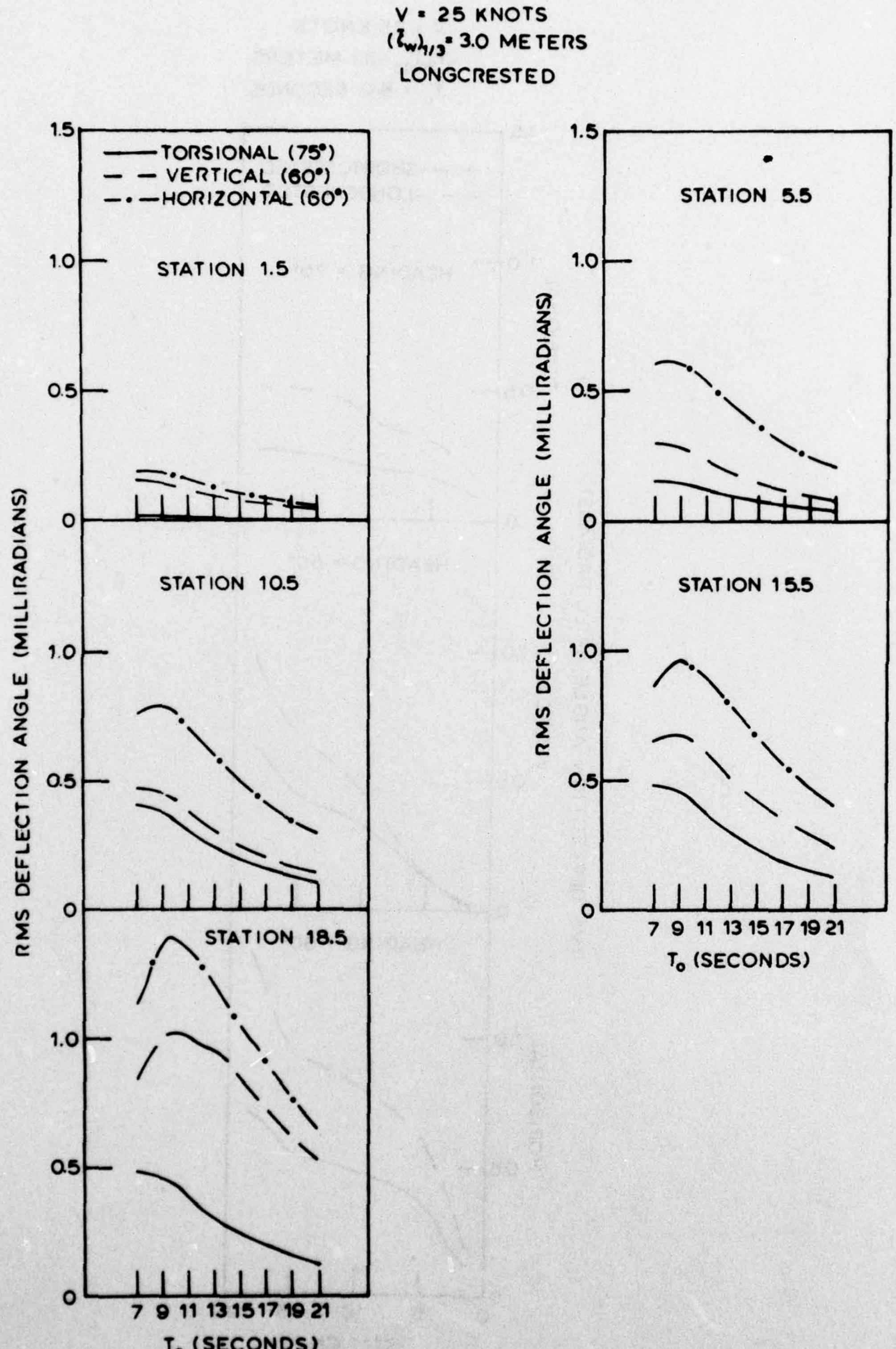

Figure 10 - Root Mean Square Deflection Angle Results for Worst Heading versus Modal Wave Period

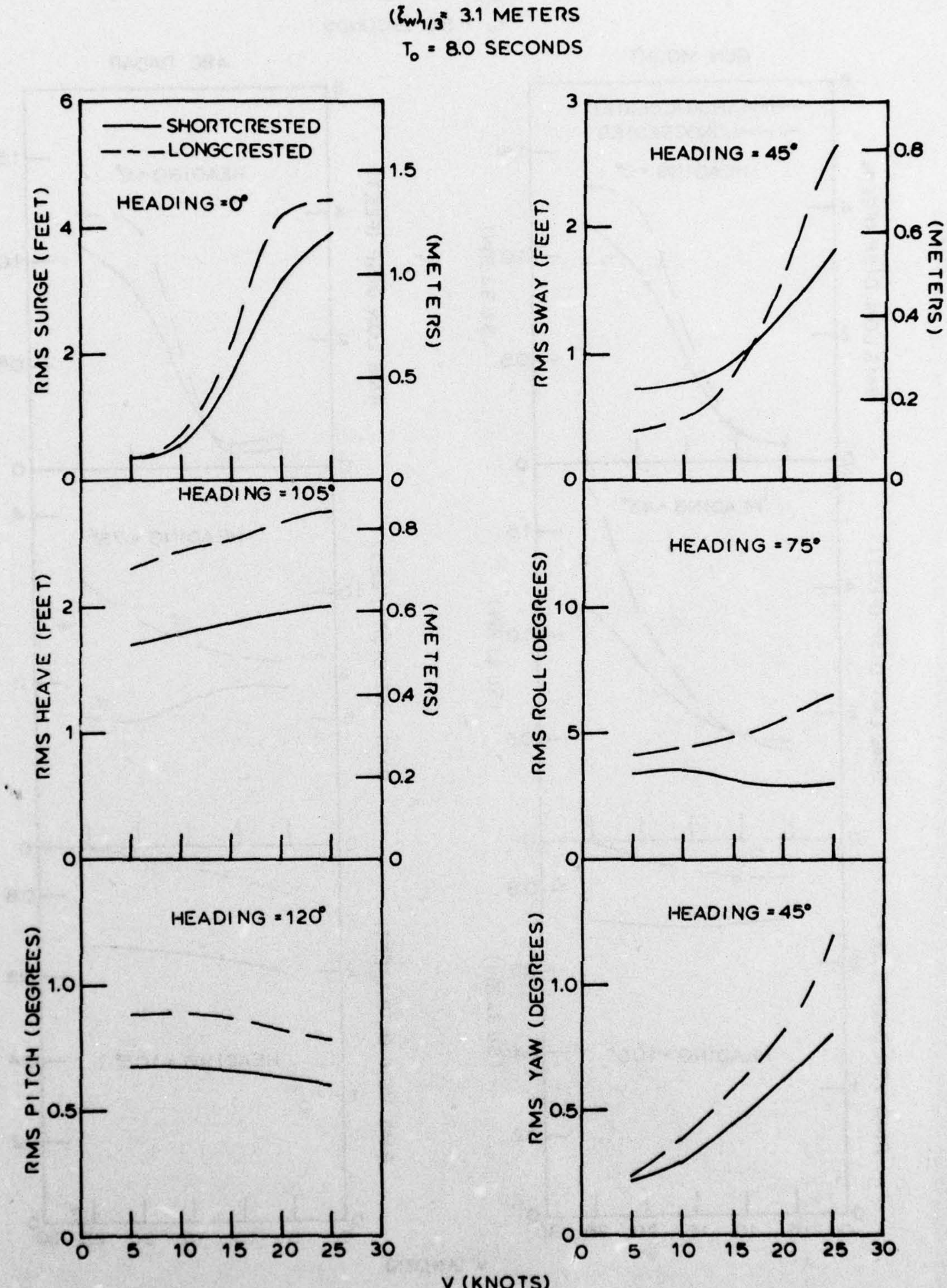

Figure 11 - Root Mean Square Motion Results of the Origin for Worst Heading versus Ship Speed

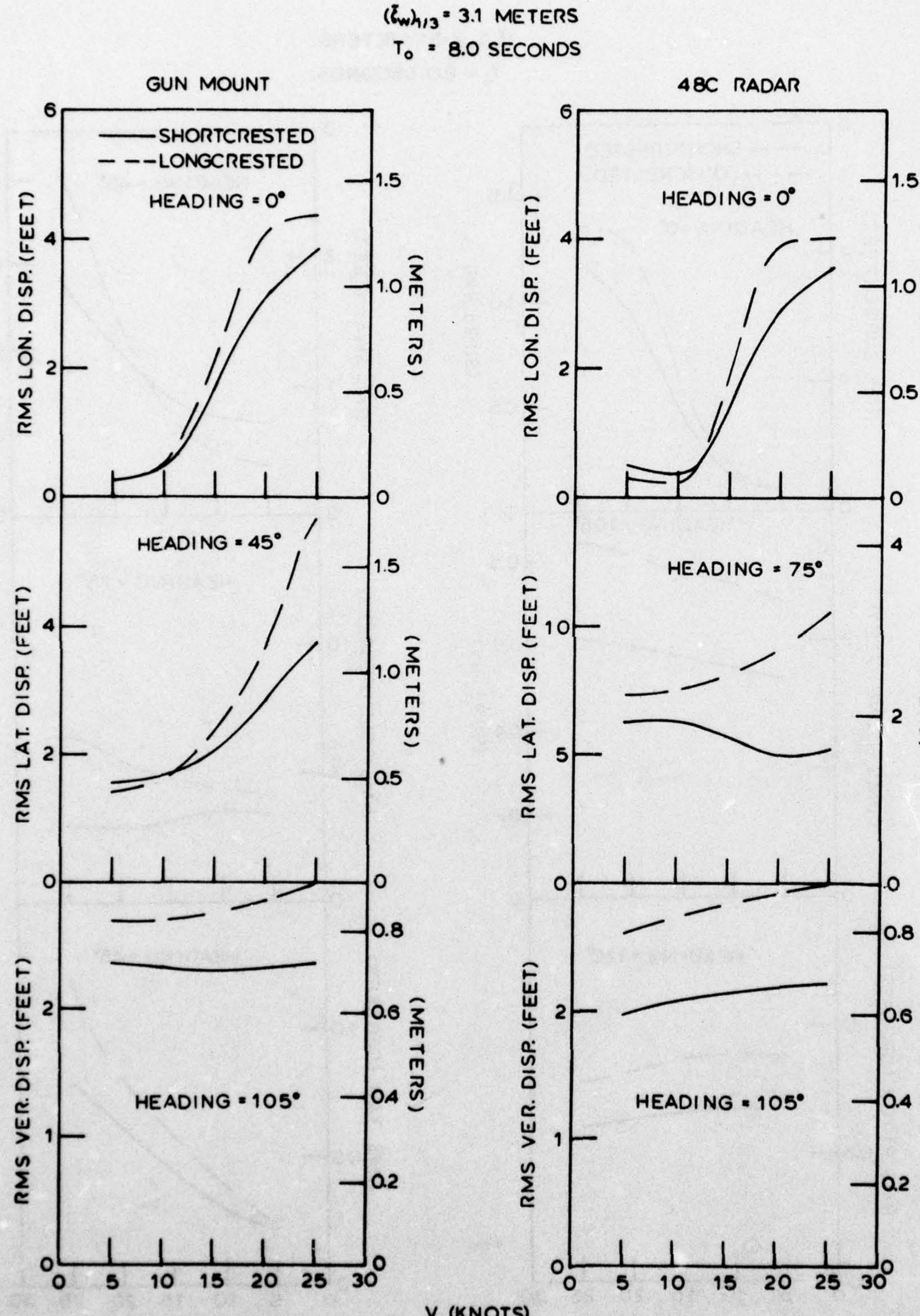

Figure 12 - Root Mean Square Motion Results of the Gun Mount and the 48C Radar for Worst Heading versus Ship Speed

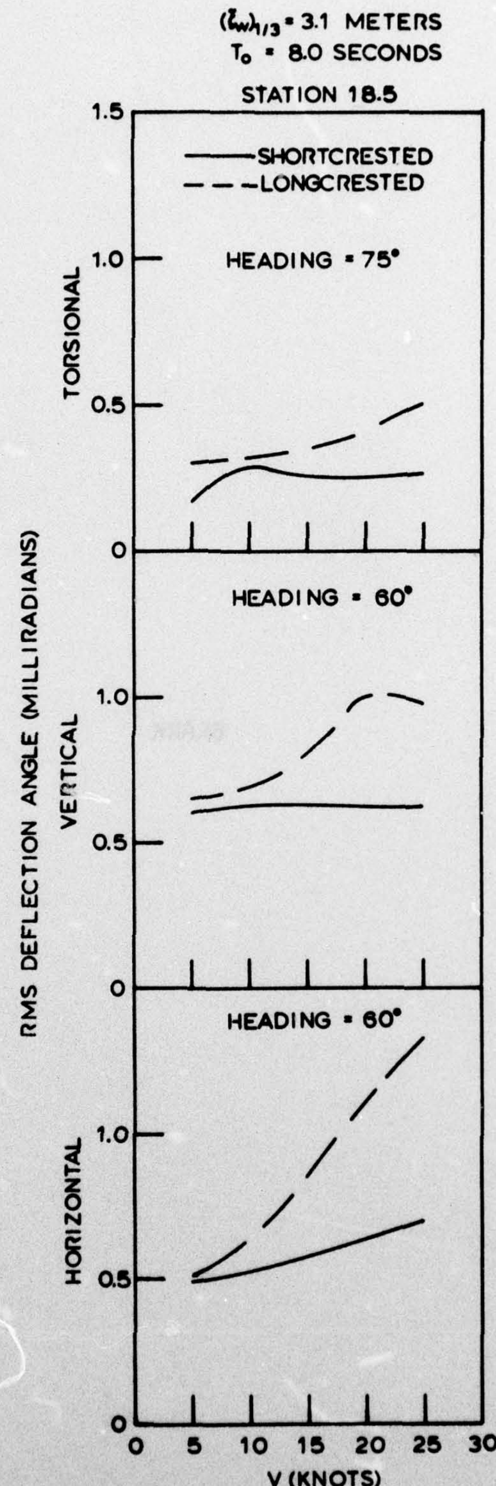

Figure 13 - Root Mean Square Deflection Angle Results of Station 18.5 for Worst Heading versus Ship Speed

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APPENDIX A
DISK PACK CONTENTS

This appendix describes the location of data files stored on private disk pack at the DTNSRDC 6600/6700 computer site. These may be accessed by any user with access to the DTNSRDC CDC 6600/6700 system using procedures described in Reference 9. All files are cataloged using ID = CHWA. Detailed examples of accessing data files are given in Reference 8.

The permanent file names (PFN) for the response time histories have the format CG26FLEXUREPRODTHxxHyyyTMzz,
where,

xx = speed in knots. This must be one of 05, 10, 20, or 25.

yyy = heading in degrees. This must be one of -30, -15, 000, 015, 030, 045, 060, 090, 105, 120, 135, 150, 165, 180, 195, or 210.

zz = modal period in seconds. This must be one of 06, 08 or 09. The corresponding significant wave heights are 6.5, 10.2, and 16.9 feet respectively.

The files for the six second modal period are stored on disk pack VSN = DV4805, SN = HJPK03. The files for eight second modal periods are stored on disk pack VSN = DV4798, SN = HJPK01. The files for the nine second modal period are stored on disk pack VSN = DV4801, SN = HJPK02.

Two versions of the access program THACES are stored on private pack HJPK01 in both update and relocatable binary forms. The PFN's are

ACCESSxxUPDATE

ACCESSxxLGO

where xx = 05 or 06. Version 06 is the final version with plotting capability removed to reduce the core required. Version 05 retains the plotting capability of THACP, Reference 8, but this plotting capability has not been tested since the program was modified to handle flexures.

Files containing various intermediate results are also stored on these packs.

APPENDIX B

ACCESS COMPUTER PROGRAM DOCUMENTATION

GENERAL INTRODUCTION

The "Time History Access Computer Program," THACES, was developed to access and manipulate the basic time histories that were generated and stored to be accessed by DTNSRDC's CDC 6700 computer. This basic program therefore provides all of the essential functions that will allow the user to employ the stored ship motion data for his own specialized application. Before listing the basic capabilities of THACES, it should be noted that the development of further programs that, for example, alter the basic seaway description to include swell, or to alter the math model of the shoring loads required to keep an object resting on the ship from moving, or develop specific math models that address the specialized requirements of a given program are not excluded by the format of the present version of THACES. Such latter specialized programs would, of course, still use the accessing or read capabilities of THACP.

The program described in this appendix is Program THACP of Reference 8, extended to handle ship flexures. See Reference 8 for detailed examples of its use.

LISTING OF THACES CAPABILITIES

At present THACES provides the capability to:

(1) Read a file of origin time histories (long-crested or short-crested) from either a disk pack, main disk, or magnetic tape.

(2) Read a file of point time histories (long-crested or short-crested) as defined on following pages.

(3) Generate and save a file of short-crested origin time histories.

(4) Generate and save a file of long-crested or short-crested point time histories.

(5) Compute RMS, maximum and minimum values for origin time histories.

(6) Compute average, standard deviations, maximum and minimum values for point time histories.

(7) Interpolate flexural response.

(8) Print point time histories.

(9) Plot point time histories (not tested).

IDENTIFICATION OF ORIGIN TIME HISTORY FILE

An origin time history file is the basic ship motion data base. This file contains for one ship at one particular heading and speed a set of 31 ship response or wave height time histories. All responses on a given file are for the same speed, significant wave height, and modal period.

All ship motions, velocities, and accelerations represent responses at the origin described in Reference 2. This origin is located in the calm water waterplane, on the centerline at the longitudinal location of the center of gravity of the ship. All flexure responses are relative to Station 1/2.

The origin data file may contain either long-crested or short-crested responses and wave height. The order of the data in the file is:

(1) Wave height

(2) Surge

(3) Sway

(4) Heave

(5) Roll

(6) Pitch

(7) Yaw

(8) Surge velocity

(9) Sway velocity

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(13) Yaw velocity

(14) Surge acceleration

(15) Sway acceleration

. . .

. . .

. . .

(19) Yaw acceleration

(20) Torsional flexure at Station 5.5

(21) Vertical flexure at Station 5.5

(22) Horizontal flexure at Station 5.5

(23) Torsional flexure at Station 10.5

(24) Vertical flexure at Station 10.5

(25) Horizontal flexure at Station 10.5

(26) Torsional flexure at Station 15.5

(27) Vertical flexure at Station 15.5

(28) Horizontal flexure at Station 15.5

(29) Torsional flexure at Station 18.5

(30) Vertical flexure at Station 18.5

(31) Horizontal flexure at Station 18.5

The above flexures are relative to Station 0.5

IDENTIFICATION OF POINT TIME HISTORY FILE

Ship responses at locations other than the origin can be calculated using THACP and the origin time history file. For this purpose, the ship is assumed to rotate about its origin as a rigid body. When responses at points other

than the origin are required, these points must be located. Since the motion prediction origin is not a commonly used reference for shipboard locations of points, a new point of reference is specified at the intersection of the aft perpendicular, the longitudinal centerline, and the baseline.

The point time histories may be long-crested or short-crested and contain from 1 to 50 responses at a specified significant wave height and modal period. These responses can be:

(1) Any of the first 19 responses (wave height, ship motion, velocity or acceleration) on the origin time history file.

(2) The displacements, velocities or accelerations of the longitudinal, lateral, and vertical responses at specified points.

(3) Lateral and normal forces and loads in the ship coordinate system at specified points.

(4) Torsional, vertical, or horizontal flexure at a specified longitudinal position relative to any other specified longitudinal position. These flexures are obtained using a spline interpolation routine.

THACP DATA CARD INPUT

GENERAL

The data card input for the THACP consists of 14 data card sets. Data card set 1 specifies the type of input time history file, whether origin or point. It also specifies whether a short-crested origin time history file will be generated. Data card sets 2-7 specify the information required to generate a point time history file. Data card sets 8-10 are optional and are used to print the point time histories. Data card sets 11-14, also optional, allow the user to plot the point time histories on a Calcomp plotter. A more detailed explanation of each data card set is provided in the next section.

DESCRIPTION OF THACP INPUT DATA CARD SETS

DATA CARD SET 1, One Card, Format (I5)

ISTART, integer, column 5, program run option

ISTART = 0 (a) 11 long-crested origin time history files (TAPE20,...., TAPE30) are input. Each file represents a component heading required in the generation of a short-crested time history. The short-crested predominant heading, μ_{PRED}, is always associated with TAPE25.

$TAPE20 = \mu_{PRED} - 75°$

$TAPE21 = \mu_{PRED} - 60°$

.

.

.

$TAPE30 = \mu_{PRED} + 75°$

(b) 1 short-crested origin time history file, TAPE40, is generated with predominat heading, μ_{PRED}, associated with TAPE25.

(c) 1 short-crested point time history file, TAPE50, is generated for selected responses (NRESP>0, Data Card Set 2).

ISTART = 1 (a) 1 origin time history file, either long-crested or short-crested, is input as TAPE40. Each time history file contains a flag designating to the THACP program that the file is long-crested or short-crested. Note that TAPE20,...,TAPE30 are not input.

(b) 1 point time history file, TAPE50, is generated if NRESP>0. This file is either long-crested or short-crested depending on whether TAPE40 is long or short-crested.

ISTART = 2 (a) 1 long or short-crested point time history file, TAPE50, is input and not generated.

Data card sets 2-7 are skipped if ISTART = 2.

DATA CARD SET 2, One Card, Format (I5)

NRESP, integer, columns 4-5, number of selected responses (maximum of 50)

Remaining data card sets are skipped if NRESP = 0.

DATA CARD SET 3, One Card, Format (8A10)

TITL, alphanumeric, columns 1-80, title information for point time history tape, TAPE50

DATA CARD SET 4, One Card, Format (2F10.5)

(1) SIGWHT, floating point, columns 1-10, significant wave height in feet

(2) PERMOD, floating point columns 11-20, modal period in seconds

SIGWHT allows the user to change significant wave height, PERMOD must match the modal period of the input time history file.

DATA CARD SET 5, One Card, Format (I5)

NPOINT, integer, columns 4-5, number of points on the hull desired (maximum of 50)

Data card set 6 is skipped if NPOINT = 0.

DATA CARD SET 6, NPOINT Cards, Format (I5, 3A10, 4F10.5)

(1) IP, integer, columns 4-5, point number without regard to order, can be any number from one to 50

(2) PNTITL, alphanumeric, columns 6-35, point title

(3) XAP, floating point, columns 36-45, X coordinate measured from aft perpendicular

(4) YCL, floating point, columns 46-55, Y coordinate measured from centerline, positive to starboard

(5) ZBL, floating point, columns 56-65, Z coordinate measured from baseline at the point

(6) DBLWL, floating point, columns 66-75, vertical distance from baseline to the waterline at the longitudinal location of the point.

DATA CARD SET 7, NRESP Cards, Format (I5, 3A10, 3I5, F10.5)

(1) IRESP, integer, columns 4-5, response number

(2) RSTITL, alphanumeric, columns 6-35, response title

(3) IMOTN, integer, columns 40, response desired

IMOTN = 0 - wave height at the origin

= 1 - surge or longitudinal

= 2 - sway or lateral

= 3 - heave or vertical

= 4 - roll

= 5 - pitch

= 6 - yaw

If ITYPE = 6 (Flexure)

IMOTN = 4 gives torsional

= 5 gives vertical

= 6 gives horizontal

(4) ITYPE, integer, column 45, response type

ITYPE = 1 - displacement or angle

= 2 - velocity

= 3 - acceleration

= 4 - ship system force (including gravity)

= 5 - ship system load

= 6 - flexure

(5) IPOINT, integer, columns 46-50, point number

If IPOINT = 0, responses at the origin will be used

NOTE: If angular responses (ITYPE = 1, 2, or 3 and IMOTN = 4, 5, or 6) are requested at a point other than the origin (IPOINT = 0), the program fails.

If ITYPE = 6 (flexure), the flexure at IPOINT is determined relative to the point IPTR, specified below

For ITYPE = 5, the following additional input is required:

(6) XMU, floating point, columns 51-60, coefficient of friction used in load calculations.

For ITYPE = 6, the following additional is required:

(6) IPTR, integer, columns 51-55, specifies reference point for flexure calculation.

DATA CARD SET 8, One Card, Format (I5)

NRPRNT, integer, column 5, number of response time histories to be printed (maximum of 10)

Data card sets 9 and 10 are skipped if NRPRNT = 0.

DATA CARD SET 9, One Card, Format (2F10.5)

(1) PRSTRT, floating point, columns 1-10, printing start time in seconds

(2) PREND, floating point, columns 11-20, printing stop time in seconds

DATA CARD SET 10, NRPRNT Cards, Format (I5, A8)

(1) IRPRNT, integer, columns 1-5, response number of time history to be printed

(2) TLPRNT, alphanumeric, columns 6-13, response title of time history to be printed (8 characters)

NOTE ON PLOTTING: In version 06 of THACP the plotting capability has been removed. In version 05, the plotting routines have been retained, but have not been tested since the modifications for flexure time histories were made. If information for plot input is desired for experimental purposes, see Reference 8 for data card sets 11 through 14.

INPUT EXAMPLES

See Reference 8 for examples of input.

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